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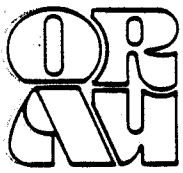

Prepared by
Oak Ridge Associated
Universities

Prepared for
Division of
Remedial Action
Projects

U.S. Department
of Energy

COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY F

NIAGARA FALLS STORAGE SITE

LEWISTON, NEW YORK

J. D. BERGER

Radiological Site Assessment Program
Manpower Education, Research, and Training Division

FINAL REPORT

February 1984

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Prepared for

U.S. Department of Energy
as part of the
Formerly Utilized Sites -- Remedial Action Program

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This report is based on work performed under contract number DE-AC05-760R00033 with the Department of Energy.

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INTRODUCTION

Beginning in 1944, the Manhattan Engineer District and its successor, the Atomic Energy Commission (AEC), used portions of the Lake Ontario Ordnance Works (presently referred to as the Niagara Falls Storage Site (NFSS) and off-site properties) approximately 3 km northeast of Lewiston, New York, for storage of radioactive wastes. These wastes were primarily residues from uranium processing operations; however, they also included: contaminated rubble and scrap from decommissioning activities, biological and miscellaneous wastes from the University of Rochester, and low-level fission-product waste from contaminated liquid evaporators at the Knolls Atomic Power Laboratory (KAPL). Receipt of radioactive waste was discontinued in 1954, and, following cleanup activities by Hooker Chemical Co., 525 hectares of the original 612 hectare site were declared surplus. This property was eventually sold by the General Services Administration to various private, commercial, and governmental agencies.[1]

SCA Chemical Services, Inc. (SCA) is the current owner of a tract from the NFSS, identified as off-site property F (see Figure 1). A radiological survey of that tract, conducted during April-June 1983, is the subject of this report.

SITE DESCRIPTION

Figure 2 is a plot plan of off-site property F. The property is approximately rectangular in shape (670 m in length by 400 m wide on the western portion and 345 m wide on the eastern portion) and occupies an area of 24.8 hectares. It is bounded on three sides by roads - Castle Garden Road on the west, M Street on the north, and MacArthur Street on the east. The southern boundary is a security fence separating SCA property from the Department of Energy's Niagara Falls Storage Site. The property is almost entirely occupied by landfills, salts areas, and waste treatment ponds; much of the original land surface has been disturbed. There are no

permanent buildings on the site. The land is essentially free of brush and weeds. The southwest corner of the property is covered by a swamp.

Radiological History

There is no evidence of contaminated waste burials on property F. However, it is likely that portions of property F were occasionally used for temporary storage due to its proximity to other properties, e.g. properties G, C′, E′, and the present NFSS, where burials or storage of radioactive waste were conducted. Contamination, if any, from previous activities has probably been relocated during disturbances of the site by the present occupants. Previous surveys have identified spotty contamination and elevated direct radiation levels along the streets forming property boundaries. [1-3] Higher radiation levels are present throughout the southern portion of the site, due to materials stored on the adjacent DOE property. The K-65 storage tower, in particular, causes significant increases in direct radiation levels along the southern boundary.

SURVEY PROCEDURES

The comprehensive survey of NFSS off-site property F was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), during the periods of April 18-29 and June 1-3, 1983. The survey was in accordance with a plan dated March 14, 1983, approved by the Department of Energy′s Office of Nuclear Energy. The objective and procedures from that plan are presented in this section.

Objective

The objective of the survey was to provide a comprehensive assessment of the radiological conditions on property F. Radiological information collected included:

1. direct radiation exposure rates and surface beta-gamma dose rates,

2. locations of elevated surface residues,
3. concentrations of radionuclides in surface and subsurface soil, and,
4. concentrations of radionuclides in subsurface water.

Procedures

1. Site Preparation

A 40 m grid system was established by McIntosh and McIntosh of Lockport, NY, under subcontract. This grid system is shown on Figure 3. In the southern portion of the property, this grid was subdivided into 20 m intervals by the survey team to provide for additional systematic soil sampling in the areas of higher ambient direct radiation levels.

2. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at each accessible 40 m grid interval. Measurements were performed using portable gamma NaI (Tl) scintillation survey meters. Conversion of these measurements to exposure rates in microroentgens per hour (μR/h) was in accordance with cross calibration with a pressurized ionization chamber.

3. Beta-gamma dose rate measurements were performed 1 cm above the surface at each accessible 40 m grid interval. These measurements were conducted using thin-window (<7 mg/cm^2) G-M detectors and portable scaler/ratemeters. At selected locations, measurements were also obtained with the detector shielded to evaluate contributions of non-penetrating beta and low-energy photon radiations. Meter readings were converted to dose-rate in microrads per hour (μrad/h), based on cross calibration with a thin-window ionization chamber.

4. Surface (0-15 cm) soil samples of approximately 1 kg each were collected at or near each accessible 40 m grid interval

throughout the property and at each accessible 20 m grid interval on the southern portion of the property.

5. Walkover surface scans were conducted over all accessible areas of the property. Scanning intervals were 1-2 m along roadways and 2-5 m on all other portions of the site. Portable gamma scintillation survey meters were used for these scans. Locations of elevated contact radiation levels were noted and surface exposure rates were measured at these locations.

6. At selected locations of elevated surface radiation levels, beta-gamma dose rates and exposure rates at 1 m above the surface were also measured. Surface soil samples were obtained from seven of these locations and, following sampling, the surface exposure levels were remeasured to evaluate the effectiveness of shallow sampling on removal of the radiation source. The locations where these additional measurements and samples were obtained are indicated on Figure 3.

7. Detection Sciences Group of Carlisle, MA, performed ground penetrating radar surveys at locations selected for subsurface sampling. The purpose of these radar scans was to identify the presence of underground piping or utilities which would preclude borehole drilling.

8. Boreholes were drilled to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface soil and water samples. Seven boreholes were drilled to ground water depth (3-6 m), by Site Engineers, Inc., of Cherry Hill, NJ, using a truck-mounted 20 cm diameter hollow-stem auger. The locations of these boreholes, shown on Figure 4, were selected to provide representative sampling of the property. Due to the presence of landfills and other waste handling areas, boreholes could not be drilled on the property interior without jeopardizing these control features.

A gamma scan of each borehole was performed to identify elevated radiation levels, which would indicate subsurface residues. Radiation profiles in the boreholes were determined by measurements of gamma radiation at 15-30 cm intervals between the surface and the hole bottom. A collimated gamma scintillation detector and portable scaler were used for these measurements.

Ground water samples of approximately 3.5 liters each were collected from the boreholes, using a hand bailer. Subsurface soil samples were collected from various depths by scraping the sides of the borehole with a specially constructed sampling tool.

9. Twenty soil samples and seven water samples were collected from the Lewiston area (but not on the NFSS or associated off-site properties) to provide baseline concentrations of radionuclides for comparison purposes. Direct background radiation levels were measured at locations where baseline soil samples were collected. The locations of the baseline samples and background measurements are shown on Figure 5.

Sample Analyses and Interpretation of Results

Soil samples were analyzed by gamma spectrometry. Radium-226 was the major radionuclide of concern, although spectra were reviewed for Cs-137, U-235, U-238, and other gamma emitters.

Water samples were analyzed for gross alpha and beta concentrations. Radium-226 analyses were performed on water samples exceeding the EPA drinking water standards for gross alpha activity. Analysis for Sr-90 was also performed on one sample. Additional information concerning analytical equipment and procedures is contained in Appendix A.

Results of this survey were compared to applicable guidelines for formerly utilized radioactive materials handling sites as presented in Appendix B.

RESULTS

Background Levels and Baseline Concentrations

Background exposure rates and baseline radionuclide concentrations in soil, determined for 20 locations in the vicinity of NFSS are presented in Table 1-A. Exposure rates ranged from 6.8 to 8.8 μR/h (typical levels for this area of New York). Concentrations of radionuclides in soil were: Ra-226, <0.09 to 1.22 pCi/g (picocuries per gram); U-235, <0.14 to 0.46 pCi/g; U-238, <2.20 to 6.26 pCi/g; Th-232, 0.32 to 1.18 pCi/g; and Cs-137, <0.02 to 1.05 pCi/g. These concentrations are typical of the radionuclide levels normally encountered in surface soils.

Radioactivity levels in baseline water samples are presented in Table 1-B. The gross alpha and gross beta concentrations ranged from 0.55 to 1.87 pCi/l (picocuries per liter) and <0.63 to 14.3 pCi/l, respectively. These are typical of concentrations normally occurring in surface water.

Direct Radiation Levels

Direct radiation levels, measured at 40 m grid intervals, are presented in Table 2. The gamma exposure rates at 1 m above the surface at these locations ranged from 5 to 30 μR/h (average 11 μR/h). At surface contact the exposure rates ranged from 5 to 31 μR/h with an average of 11 μR/h, and the beta-gamma dose rates ranged from 6 to 51 μrad/h (average 21 μrad/h). Dose rate measurements performed with the detector shielded averaged approximately 20% less than those with the unshielded detector. This indicates only a small portion of the surface dose rate is due to nonpenetrating beta or low-energy photon radiations.

Direct radiation levels measured at the 40 m intervals were generally higher along the southern boundary, particularly near the southeast corner of the property. This is due to the radioactive K-65 residues stored in the water tower on the adjacent DOE property. Additional measurements of gamma exposure rates near the south boundary fence indicate a maximum level of 42 μR/h at grid point 350S,850E. Figure 6 shows the isopleths for 20, 30 and 40 μR/h at 1 m above the surface on property F.

The walkover survey identified two areas of generally elevated direct radiation levels. These areas were at grid coordinates 132-140S,480-505E and 124-136S, 520-532E. Contact exposure rates at these locations ranged from 17 to 60 μR/h. The higher radiation levels in these two areas are believed to be primarily due to the presence of fly ash, which has been mixed with chemical wastes prior to their disposal. Fly ash typically contains slightly elevated concentrations of naturally occurring radionuclides from the uranium and thorium decay series. Ten additional isolated locations of elevated contact radiation levels were noted on property F. Exposure rates in contact with these locations ranged from 14 to 2900 μR/h. The maximum level was at grid point 130S,720E. At 1 m above the surface the exposure rates ranged from 6 to 14 μR/h; beta-gamma dose rates at these isolated locations ranged from 33 to 16,800 μrad/h. The locations of the elevated areas identified by the walkover scan are shown on Figure 3; direct radiation levels associated with these areas are presented in Table 3.

At grid location 130S,720E, identified by the scan, surface soil sampling was effective in greatly reducing the radiation level. This indicates that the contaminant was in the form of a discrete particle or small object. At several other locations the contact exposure rates were not significantly changed as a result of soil sampling, suggesting that the contamination at these locations extends greater than 15 cm below the surface and/or is diffused rather than in discrete particles.

Many of the isolated areas of contamination were located adjacent to main roads - a situation noted on other off-site properties and suggesting spillage of small quantities of residues or wastes from containers during transportation, loading and unloading, or temporary roadside storage. Other isolated areas were associated with earthen berms and regions of fill. It is suspected that some of this contamination was relocated to property F from other off-site properties during construction of the landfills and treatment ponds.

Radionuclide Concentrations in Surface Soil

Table 4 lists the concentrations of radionuclides measured in surface soil collected at 40 m and 20 m grid intervals. These samples contained Ra-226 concentrations ranging from <0.43 to 1.78 pCi/g. With only a few exceptions, the Ra-226 concentrations were in the range of the baseline samples. Concentrations of U-235, U-238, and Cs-137 were not significantly different from those in baseline samples.

Radionuclide concentrations in samples from areas of elevated contact radiation levels, identified by the walkover scan, are presented in Table 5. All of these samples contained Ra-226 concentrations above those in baseline samples; the highest levels were in samples B2 and B4B. These samples contained small chips of lead cake residue with Ra-226 levels of 20 μCi and 2.8 μCi, respectively. Levels of uranium in these samples were also elevated, with the highest concentration being 12.6 pCi/g in sample B1. Samples from the areas where fly ash is mixed with chemical waste contained concentrations of Ra-226 and U-238 only slightly higher than those in baseline samples. These samples also contained Ag-110m and very low levels of Co-60. The source of these radionuclides is not known but, due to the short half-life of Ag-110m (295 days) it is unlikely that this contaminant is the result of previous MED/AEC activities on the site.

Borehole Gamma-Logging Measurements

Gamma scintillation measurements performed in boreholes did not identify evidence of subsurface contamination.

Radionuclide Concentrations in Subsurface Soil

Table 6 presents the radionuclide concentrations measured in soil samples from boreholes. None of these samples contained Ra-226 or other gamma emitting radionuclides outside the ranges determined in baseline soil.

Radionuclide Concentrations in Water

Radionuclide concentrations in water samples obtained from boreholes are presented in Table 7. Most of these samples contained gross alpha and gross beta concentrations above those in the baseline water samples. It should be noted that all of the samples also contained high concentrations of dissolved solids - possibly due to chemical disposal activities on this site. Dissolved solids result in residues, which adversely affect the detection sensitivities of the gross alpha procedure.

The highest gross alpha concentration of 21.5 pCi/l was noted in sample W6 from borehole H6; the highest gross beta concentration of 102 pCi/l was in sample W1 from borehole H1. Samples W1, W3, W5, W6, and W7 were analyzed for Ra-226. The maximum Ra-226 concentration measured was 1.47 pCi/l (sample W1) - well below the EPA Interim Drinking Water Standard. Sample W1 was also analyzed for Sr-90; the concentration of this radionuclide was <0.27 pCi/l - also well below the EPA standard of 8 pCi/l.

COMPARISON OF SURVEY RESULTS WITH GUIDELINES

The guidelines applicable to cleanup of the off-site properties at NFSS are presented in Appendix B. On property F the maximum gamma exposure rate measured at 1 m above the surface is 42 μR/h total or about 34 μR/h above background; the average level is 11 μR/h. These levels are below the 60 μR/h Nuclear Regulatory Commission criteria for open land areas.

Results of the walkover scan and analysis of surface soil samples indicate isolated areas with Ra-226 soil concentrations exceeding 5 pCi/g. These locations are shown on Figure 7. Sampling at several other isolated spots was effective in completely removing small chips of contaminated residue. Analysis of samples B6 and B7 from the two areas of generally elevated radiation levels (132-140S, 480-505E and 124-136S, 520-532E) indicates that the major radionuclide in these areas is Ag-110m. Concentrations of 10.9 and 27.7 pCi/g were found in samples collected from these elevated areas. This radionuclide is not attributable to the previous Manhattan Engineer District or Atomic Energy Commission activities at this site. Its presence on this property is unexplained.

Borehole logging and sampling did not identify any areas of subsurface radionuclide concentrations exceeding the guidelines. Subsurface water from two boreholes exceeded 15 pCi/l gross alpha. One of the samples exceeded 50 pCi/l gross beta. Analysis for Ra-226 and Sr-90, respectively, in these samples indicated concentrations are below the EPA limits for these radionuclides.

SUMMARY

A comprehensive survey of off-site property F at the Niagara Falls Storage Site was conducted during April-June 1983. The survey included surface radiation scans, measurements of direct radiation levels, and analysis for radionuclide concentrations in surface and subsurface soil samples, and in subsurface water samples. The results of the survey indicated elevated direct radiation levels on the southern (particularly the southeastern) portion of the property. These levels are primarily due to the residues, containing Ra-226, stored in the water tower on the adjacent Department of Energy site. The maximum level of 42 μR/h is within the NRC guidelines for unrestricted areas.

Several surface areas, having Ra-226 soil contamination exceeding 5 pCi/g, were noted (see Figure 7). These locations were small and isolated and, in each case, radionuclide concentrations averaged over an area of 100 m^2 would be within the applicable criteria. Subsurface sampling and measurements indicate that contamination is limited to the top 15-30 cm of soil. Ag-110m was identified in two areas used for mixing chemical wastes. Although the source of this radionuclide was not determined, it is not attributed to previous federal government activities at the site. These two areas are therefore not subject to the cleanup criteria established for formerly utilized sites.

Although elevated direct radiation levels and isolated areas of surface soil Ra-226 contamination are present on property F, under present

conditions of usage the contaminants do not pose potential health risks to workers of the general public. There is no evidence that migration of the radioactive materials is adversely affecting adjacent properties or the ground water.

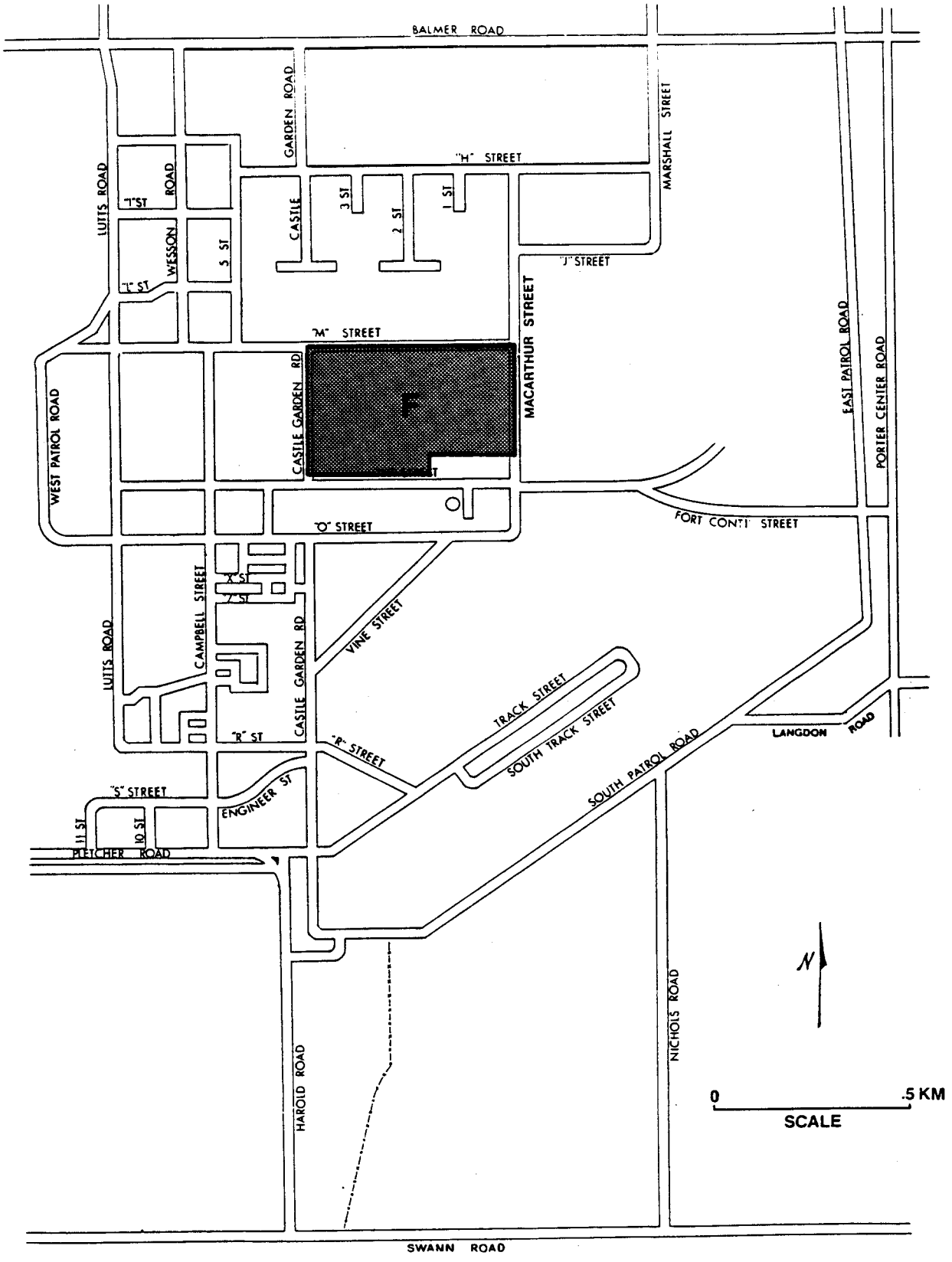

FIGURE 1. Map of the Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Off-Site Property F.

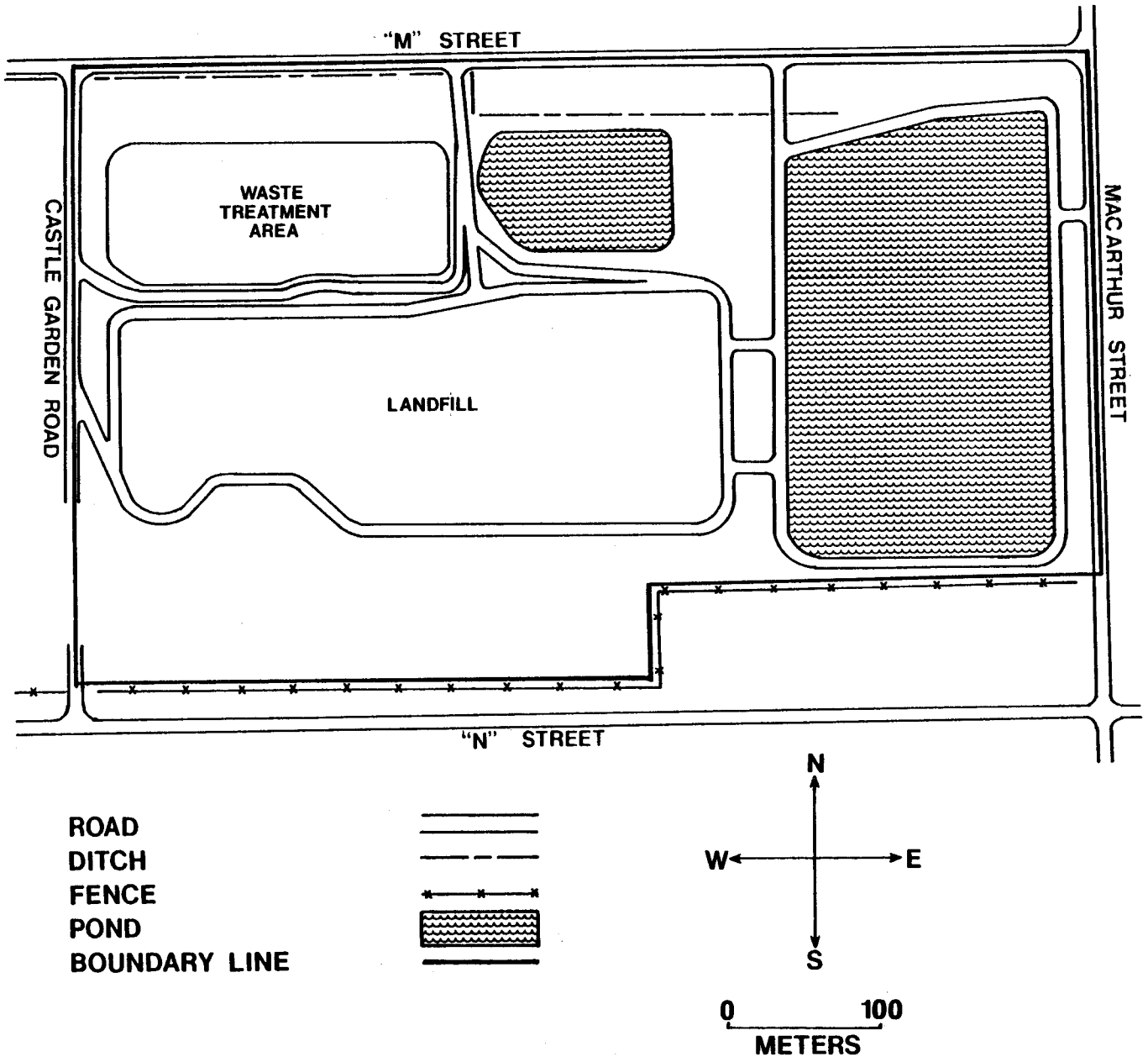

FIGURE 2. Plan View of NFSS Off-Site Property F Indicating Prominent Surface Features.

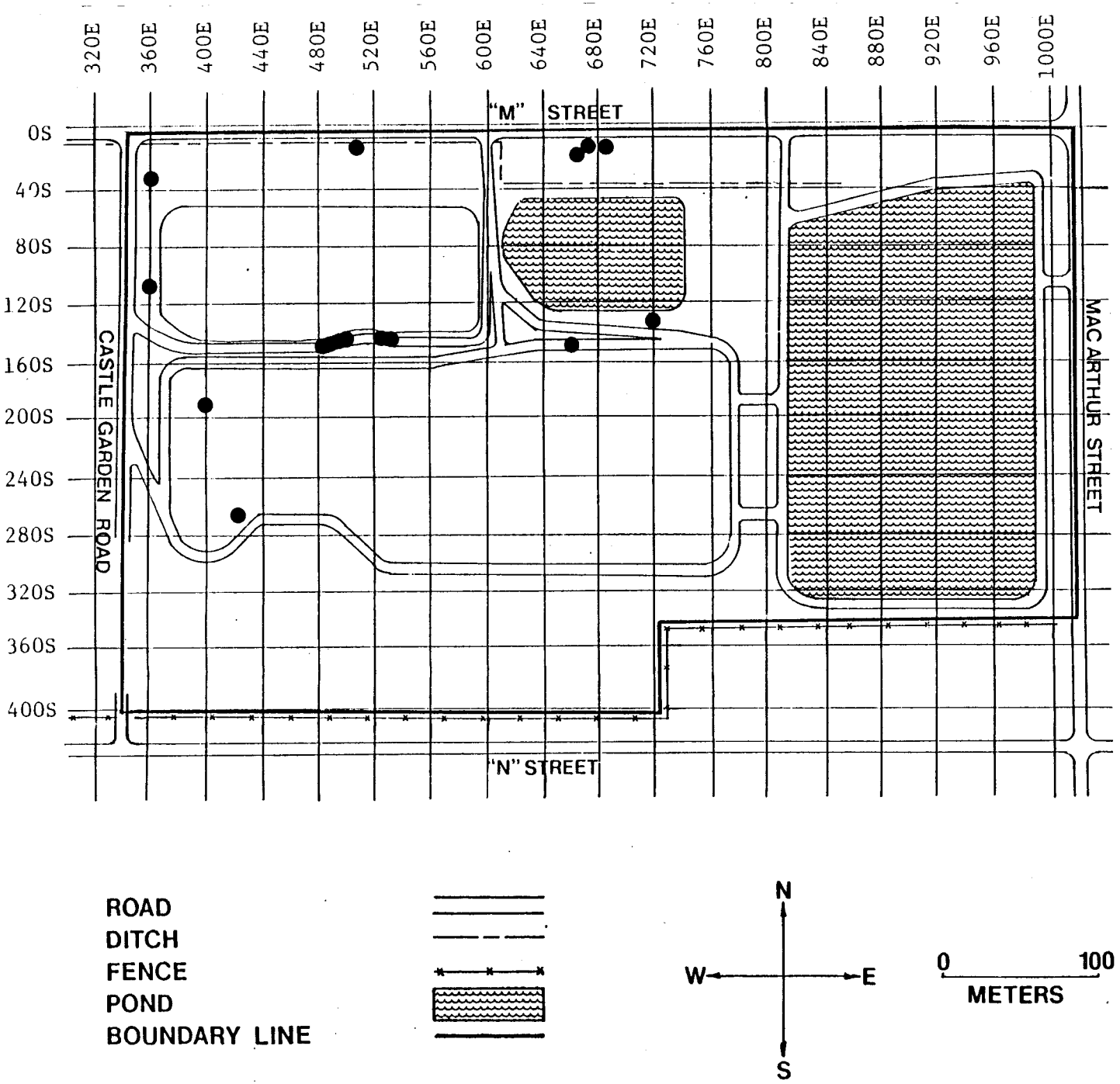

FIGURE 3. Locations of Elevated Surface Radiation Levels Identified by the Walkover Scan.

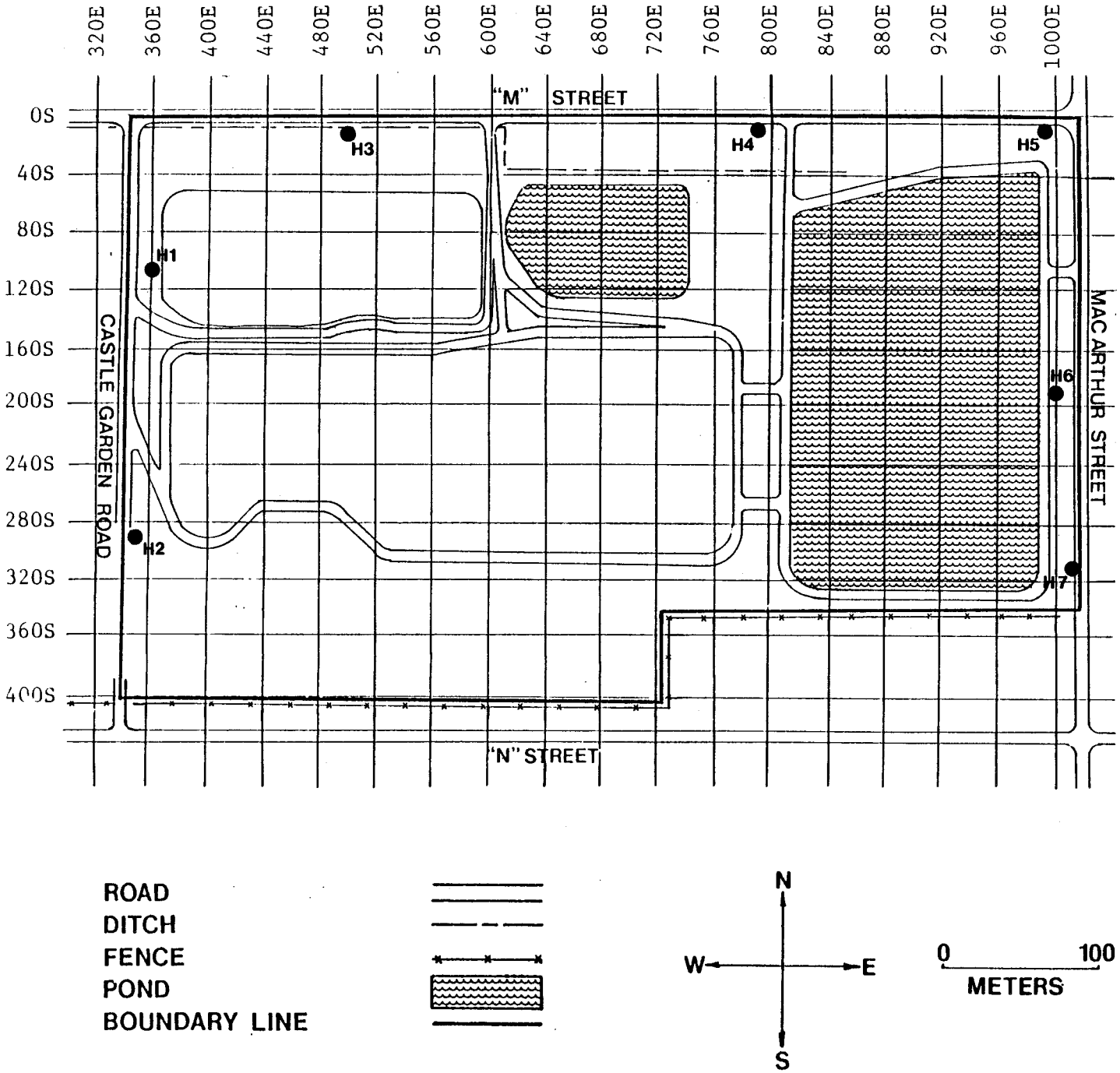

FIGURE 4. Locations of Boreholes for Subsurface Investigations.

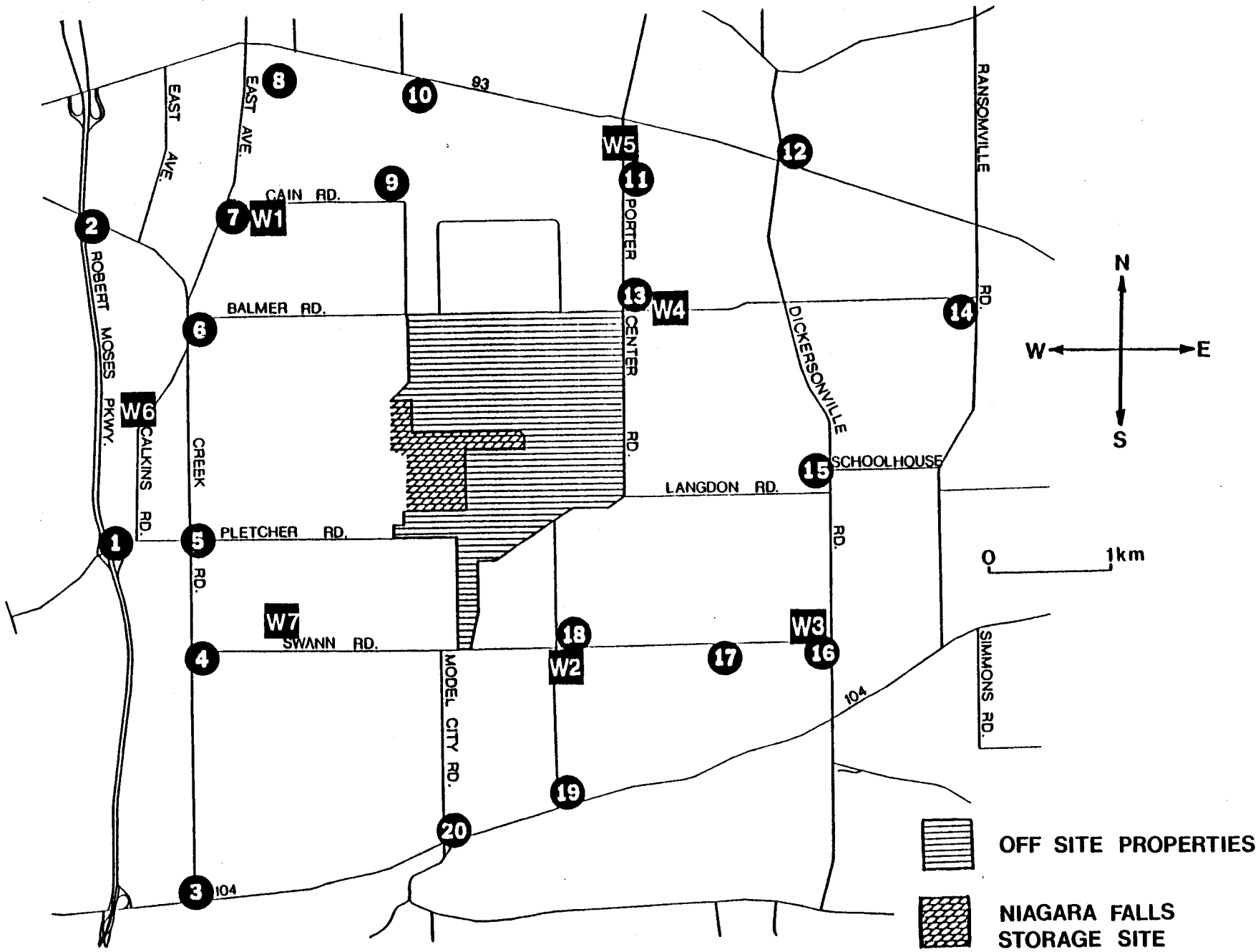

FIGURE 5. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples. (#1-20: soil samples and direct measurements; W1-W7: water samples.)

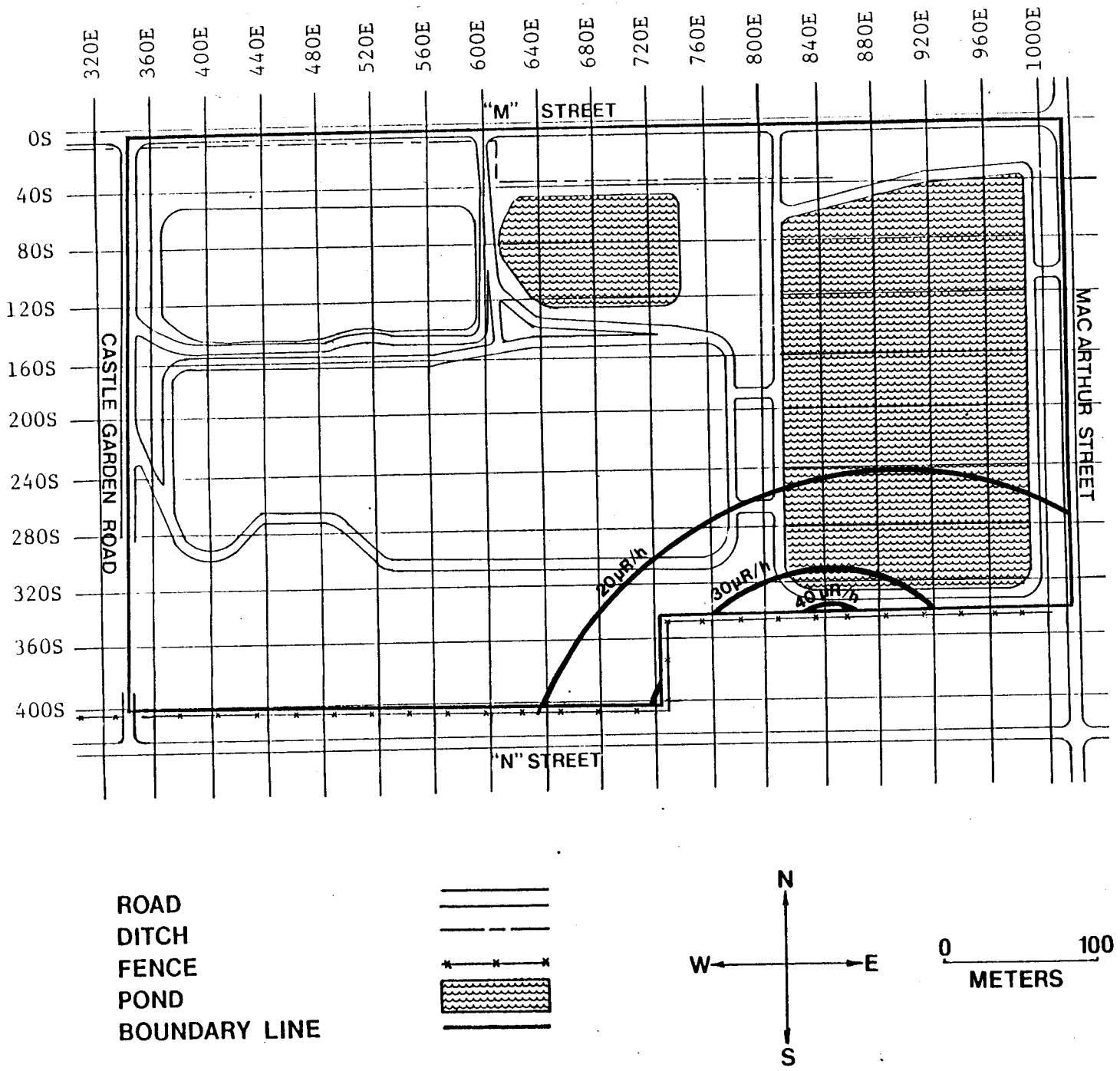

FIGURE 6. Exposure Rates (μR/h) Measured at 1 m Above the Surface on Property F.

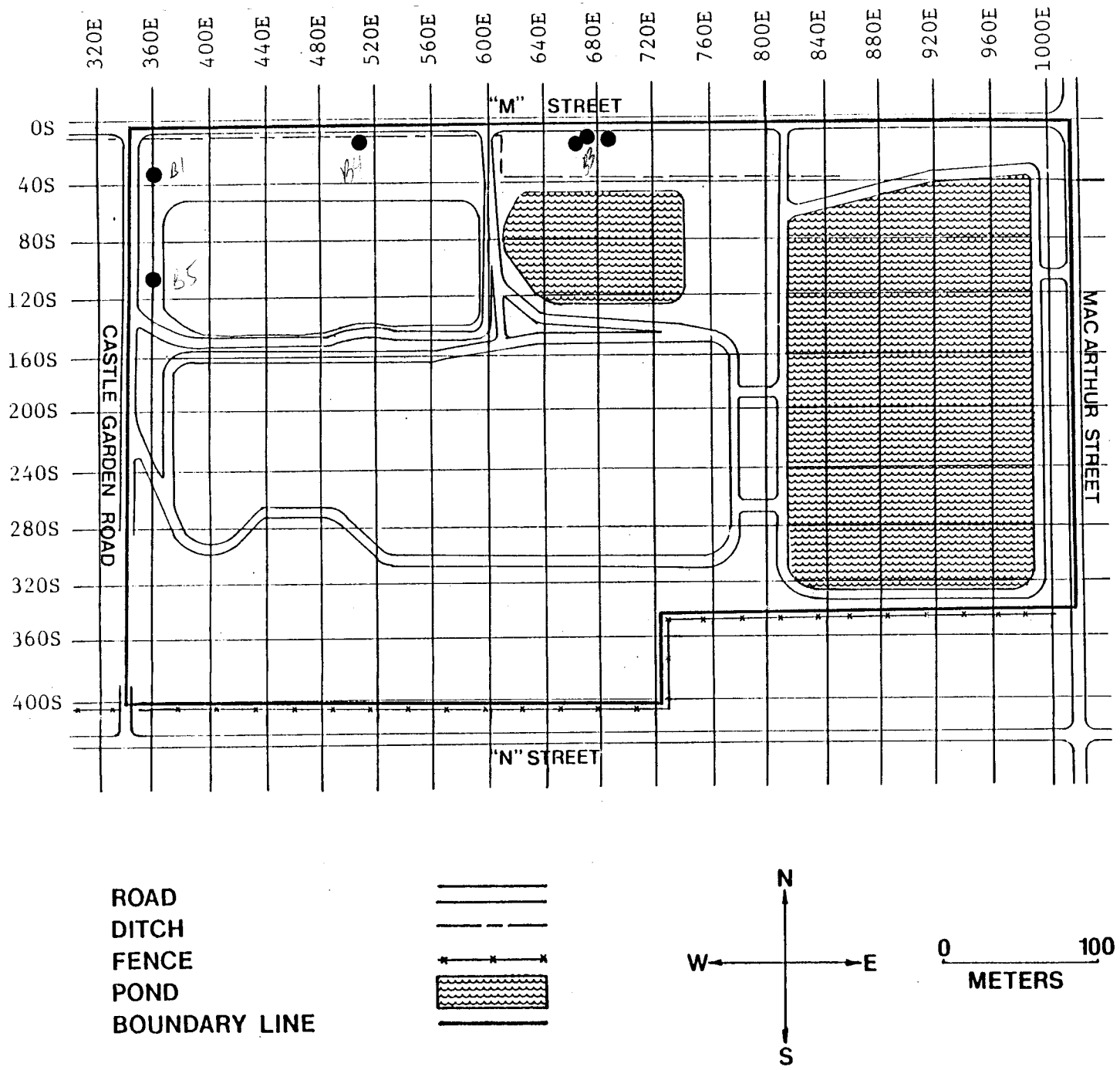

FIGURE 7. Locations on Property F Where Radionuclide Concentrations in Soil Exceed the Criteria for Formerly Utilized Sites.

TABLE 1-A

BACKGROUND EXPOSURE RATES
AND
RADIONUCLIDE CONCENTRATIONS IN BASELINE SOIL SAMPLES

Location[a]	Exposure Rate[b] (μR/h)	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
1	6.8	0.74 ± 0.16[c]	<0.19	<2.89	0.70 ± 0.46	0.29 ± 0.08
2	6.8	0.75 ± 0.19	<0.19	<3.35	0.86 ± 0.24	0.24 ± 0.08
3	8.3	0.71 ± 0.18	0.46 ± 0.41	<3.72	0.88 ± 0.33	0.34 ± 0.09
4	7.9	0.67 ± 0.18	<0.22	<4.10	1.18 ± 0.35	0.12 ± 0.07
5	7.3	0.70 ± 0.16	<0.17	<3.34	0.68 ± 0.24	0.35 ± 0.08
6	7.7	0.50 ± 0.15	<0.16	<2.33	0.52 ± 0.38	0.17 ± 0.09
7	7.7	0.63 ± 0.13	<0.17	<2.73	0.83 ± 0.24	0.35 ± 0.08
8	7.6	0.59 ± 0.12	<0.14	<2.20	0.54 ± 0.23	<0.02
9	7.1	0.63 ± 0.20	<0.23	<4.16	0.83 ± 0.38	0.69 ± 0.11
10	7.1	0.70 ± 0.16	<0.19	<2.98	0.59 ± 0.25	0.69 ± 0.10
11	6.7	<0.09	<0.19	<2.83	0.49 ± 0.31	0.48 ± 0.14
12	7.1	0.48 ± 0.13	<0.16	<2.84	0.65 ± 0.26	0.68 ± 0.10
13	6.7	0.57 ± 0.14	<0.17	<2.36	0.49 ± 0.26	0.41 ± 0.08
14	6.8	0.68 ± 0.17	<0.19	<3.24	0.67 ± 0.25	0.70 ± 0.10
15	8.2	0.65 ± 0.14	<0.17	<3.20	0.72 ± 0.35	0.23 ± 0.08
16	7.4	0.91 ± 0.17	<0.71	<3.58	0.83 ± 0.28	0.61 ± 0.09
17	7.0	0.48 ± 0.14	<0.16	<2.73	0.32 ± 0.22	0.38 ± 0.08
18	7.7	0.73 ± 0.16	<0.18	6.26 ± 9.23	1.01 ± 0.44	0.32 ± 0.12
19	8.8	1.22 ± 0.22	<0.23	<3.79	1.08 ± 0.49	1.05 ± 0.13
20	8.6	0.83 ± 0.17	<0.21	<3.59	0.84 ± 0.29	0.08 ± 0.07
Range	6.8 to 8.8	<0.09 to 1.22	<0.14 to 0.46	<2.20 to 6.26	0.32 to 1.18	<0.02 to 1.05

[a] Refer to Figure 5.
[b] Measured at 1 m above the surface.
[c] Errors are 2σ based on counting statistics.

TABLE 1-B

RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

Location[a]	Radionuclide Concentrations (pCi/l)	
	Gross Alpha	Gross Beta
W1	0.95 ± 0.93 [b]	4.79 ± 1.15
W2	0.95 ± 0.94	9.17 ± 1.31
W3	0.55 ± 0.78	2.73 ± 1.05
W4	0.63 ± 0.89	5.37 ± 1.17
W5	0.73 ± 0.68	<0.64
W6	1.87 ± 1.84	14.3 ± 2.4
W7	1.16 ± 0.66	<0.63
Range	0.55 to 1.87	<0.63 to 14.3

[a] Refer to Figure 5.
[b] Errors are 2σ based on counting statistics.

TABLE 2

DIRECT RADIATION LEVELS
MEASURED AT 40 M GRID INTERVALS

Grid Location S	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
0	360	6	6	6
0	400	8	8	12
0	440	7	7	7
0	480	7	8	9
0	520	6	5	6
0	560	6	6	6
0	600	5	5	12
0	640	6	6	6
0	680	6	6	6
0	720	7	7	8
0	760	6	7	7
0	800	7	6	6
0	840	7	7	7
0	880	7	6	6
0	920	8	8	8
0	960	7	6	8
0	1000	6	6	6
40	360	8	8	25
40	400	8	8	12
40	440	8	7	7
40	480	8	7	10
40	520	8	8	8
40	560	7	7	14
40	600	8	7	11
40	640	7	7	10
40	680	8	8	12
40	720	8	8	8
40	760	8	8	8
40	800	7	8	12
40	840	7	7	7
40	880	8	8	8
40	920	8	8	8
40	960	7	8	10
40	1000	8	8	12
80	360	8	8	25
80	400	a	a	a
80	440	a	a	a

TABLE 2, cont.

DIRECT RADIATION LEVELS
MEASURED AT 40 M GRID INTERVALS

Grid Location S	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
80,	480	a	a	a
80,	520	a	a	a
80,	560	a	a	a
80,	600	7	6	6
80,	640	a	a	a
80,	680	a	a	a
80,	720	a	a	a
80,	760	8	8	15
80,	800	8	8	14
80,	840	a	a	a
80,	880	a	a	a
80,	920	a	a	a
80,	960	a	a	a
80,	1000	8	8	10
120,	360	7	7	21
120,	400	a	a	a
120,	440	a	a	a
120,	480	a	a	a
120,	520	a	a	a
120,	560	a	a	a
120,	600	7	7	7
120,	640	8	8	12
120,	680	8	8	8
120,	720	8	9	17
120,	760	9	9	18
120,	800	9	8	24
120,	840	a	a	a
120,	880	a	a	a
120,	920	a	a	a
120,	960	a	a	a
120,	1000	8	9	19
160,	360	7	8	24
160,	400	8	8	17
160,	440	8	8	28
160,	480	8	8	22
160,	520	9	10	20
160,	560	9	9	22

TABLE 2, cont.

DIRECT RADIATION LEVELS
MEASURED AT 40 M GRID INTERVALS

Grid Location S E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
160, 600	8	9	51
160, 640	9	9	9
160, 680	9	9	15
160, 720	10	10	21
160, 760	11	10	34
160, 800	12	12	22
160, 840	a	a	a
160, 880	a	a	a
160, 920	a	a	a
160, 960	a	a	a
160,1000	9	9	17
200, 360	7	8	23
200, 400	8	8	18
200, 440	8	8	17
200, 480	8	8	18
200, 520	9	9	9
200, 560	9	10	15
200, 600	10	10	18
200, 640	12	12	29
200, 680	12	12	15
200, 720	13	12	32
200, 760	14	14	15
200, 800	14	14	24
200, 840	a	a	a
200, 880	a	a	a
200, 920	a	a	a
200, 960	a	a	a
200,1000	16	16	25
240, 360	8	8	8
240, 400	8	8	19
240, 440	8	8	15
240, 480	9	9	29
240, 520	9	9	27
240, 560	10	10	14
240, 600	11	12	23
240, 640	12	13	20
240, 680	14	14	27

TABLE 2, cont.

DIRECT RADIATION LEVELS
MEASURED AT 40 M GRID INTERVALS

Grid Location S E	Gamma Exposure Rates at 1 m above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
240, 720	16	16	33
240, 760	18	18	45
240, 800	18	18	29
240, 840	a	a	a
240, 880	a	a	a
240, 920	a	a	a
240, 960	a	a	a
240,1000	16	16	47
280, 360	7	7	17
280, 400	8	8	22
280, 440	8	8	25
280, 480	8	8	28
280, 520	9	9	26
280, 560	13	12	22
280, 600	13	13	30
280, 640	14	14	34
280, 680	16	16	40
280, 720	18	18	42
280, 760	21	21	41
280, 800	23	23	44
280, 840	a	a	a
280, 880	a	a	a
280, 920	a	a	a
280, 960	a	a	a
280,1000	24	18	34
320, 360	a	a	a
320, 400	a	a	a
320, 440	a	a	a
320, 480	a	a	a
320, 520	10	10	10
320, 560	12	12	18
320, 600	14	14	23
320, 640	16	16	29
320, 680	17	27	33
320, 720	21	21	31
320, 760	27	27	34
320, 800	30	31	50

TABLE 2, cont.

DIRECT RADIATION LEVELS
MEASURED AT 40 M GRID INTERVALS

Grid Location S	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
320,	840	30	30	44
320,	880	29	30	41
320,	920	27	28	37
320,	960	29	28	45
320,	1000	25	27	48
360,	360	a	a	a
360,	400	a	a	a
360,	440	a	a	a
360,	480	a	a	a
360,	520	a	a	a
360,	560	12	12	23
360,	600	13	13	17
360,	640	14	13	29
360,	680	15	14	27
360,	720	16	16	36
400,	360	10	10	29
400,	400	12	12	25
400,	440	12	12	21
400,	480	13	13	29
400,	520	14	14	38
400,	560	15	15	29
400,	600	16	15	28
400,	640	16	15	35
400,	680	21	20	36
400,	720	25	24	46

[a] Location inaccessible due to presence of surface water.

TABLE 3

DIRECT RADIATION LEVELS AT LOCATIONS
IDENTIFIED BY THE WALKOVER SURFACE SCAN

Grid Point[a] S	Grid Point[a] E	Exposure Rate (μR/h) Contact	Exposure Rate (μR/h) 1 m Above Surface	Surface Dose Rate (μrad/h)	Sample[b]	Contact Exposure Rate After Sample Removal (μR/h)
36	360	25	12	79	B1	21
130	720	2,900	14	16,800	B2	13
10	677	20	7	41	B3	21
11	510	57	7	57	B4 (A&B)	14
108	358	31	7	66	B5	21
132-140	480-505	27-60	9-10	--[c]	--	--
140	483	25	10	33	B6	25
124-136	520-532	17-48	8-10	--	--	--
128	523	44	9	124	B7	46
18	670	18	8	--	--	--
9	684	20	6	--	--	--
150	658	14	8	--	--	--
190	400	14	8	--	--	--
264	418	14	8	--	--	--

[a] Refer to Figure 3.
[b] Radionuclide concentrations are presented in Table 5.
[c] Dash indicates sampling or measurement was not performed.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES FROM 40 M AND 20 M GRID INTERVALS

Grid Locations S	Grid Locations E	Radionuclide Concentrations (pCi/g) Ra-226	U-235	U-238	Cs-137
10[b]	360	0.54 ± 0.25[a]	<0.16	<0.67	0.09 ± 0.08
5[b]	400	1.78 ± 0.26	<0.23	1.16 ± 0.52	<0.04
5[b]	440	1.55 ± 0.26	<0.17	1.41 ± 1.64	0.12 ± 0.08
5[b]	480	1.08 ± 0.26	<0.17	0.47 ± 0.77	0.07 ± 0.06
5[b]	520	1.15 ± 0.24	<0.21	0.61 ± 0.97	<0.04
5[b]	560	1.29 ± 0.6	<0.26	2.09 ± 2.20	0.08 ± 0.06
3[b]	600	1.19 ± 0.29	<0.22	<0.75	<0.04
5[b]	640	0.66 ± 0.18	<0.16	0.96 ± 1.14	<0.03
5[b]	680	0.91 ± 0.23	<0.24	<0.84	<0.03
5[b]	720	c	c	c	c
5[b]	760	1.10 ± 0.29	<0.23	1.30 ± 2.44	<0.04
5[b]	800	0.84 ± 0.29	<0.22	<0.71	<0.04
7[b]	840	0.55 ± 0.19	<0.18	1.70 ± 1.41	<0.03
5[b]	880	0.64 ± 0.25	<0.22	<0.71	<0.04
5[b]	920	0.58 ± 0.15	<0.18	<0.65	0.11 ± 0.06
5[b]	960	0.66 ± 0.23	<0.19	1.63 ± 1.29	<0.05
5[b]	1000	0.59 ± 0.19	<0.18	1.74 ± 0.72	<0.04
40	360	1.06 ± 0.23	<0.26	<).90	0.11 ± 0.07
40	400	1.01 ± 0.27	<0.21	1.18 ± 1.09	<0.07
40	440	0.83 ± 0.29	<0.28	0.95 ± 3.20	<0.04
40	480	1.37 ± 0.33	<0.26	<0.89	<0.05
40	520	0.68 ± 0.25	<0.21	1.60 ± 1.90	<0.04
40	560	0.66 ± 0.19	0.27 ± 0.28	0.55 ± 0.68	<0.04
40	600	0.45 ± 0.16	<0.17	1.35 ± 1.24	0.04 ± 0.04
40	640	1.06 ± 0.29	<0.23	<1.02	0.44 ± 0.14
40	680	0.93 ± 0.20	<0.17	1.62 ± 0.75	0.37 ± 0.09
40	720	0.98 ± 0.26	<0.30	1.43 ± 1.71	0.46 ± 0.10
40	760	0.83 ± 0.26	<0.20	1.19 ± 1.84	0.06 ± 0.08
40	800	0.93 ± 0.21	<0.20	<0.07	<0.04
40	840	0.91 ± 0.21	<0.20	0.82 ± 0.67	<0.05
40	880	0.93 ± 0.29	<0.21	1.13 ± 0.77	0.06 ± 0.10
40	920	0.85 ± 0.24	<0.21	1.07 ± 0.67	<0.04
40	960	0.98 ± 0.20	<0.21	0.65 ± 0.48	0.05 ± 0.07
40	1000	0.93 ± 0.20	<0.20	<0.76	0.06 ± 0.08
80	360	0.63 ± 0.18	<0.12	<0.52	<0.03
80	400	c	c	c	c
80	440	c	c	c	c
80	480	c	c	c	c
80	520	c	c	c	c

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FORM 40 M AND 20 M GRID INTERVALS

Grid Locations		Radionuclide Concentrations (pCi/g)			
S	E	Ra-226	U-235	U-238	Cs-137
80	560	c	c	c	c
80	600	0.63 ± 0.21	<0.19	0.63 ± 0.96	<0.03
80	640	c	c	c	c
80	680	c	c	c	c
80	720	c	c	c	c
80	760	1.25 ± 0.31	<0.21	<0.93	0.15 ± 0.11
80	800	0.93 ± 0.24	<0.23	0.84 ± 1.62	0.26 ± 0.10
80	840	c	c	c	c
80	880	c	c	c	c
80	920	c	c	c	c
80	960	c	c	c	c
80	1000	0.75 ± 0.23	<0.17	0.46 ± 0.65	0.33 ± 0.08
120	360	0.86 ± 0.31	<0.20	1.59 ± 1.69	<0.04
120	400	c	c	c	c
120	440	c	c	c	c
120	480	c	c	c	c
120	520	c	c	c	c
120	560	c	c	c	c
120	600	c	c	c	c
120	640	0.86 ± 0.21	<0.20	<0.75	0.14 ± 0.09
125[b]	680	1.04 ± 0.30	<0.30	<1.07	<0.06
125[b]	720	0.91 ± 0.34	<0.20	<0.90	0.31 ± 0.08
120	760	1.00 ± 0.34	<0.25	<0.99	0.66 ± 0.14
120	800	0.80 ± 0.20	<0.22	1.46 ± 0.96	0.16 ± 0.08
120	840	c	c	c	c
120	880	c	c	c	c
120	920	c	c	c	c
120	960	c	c	c	c
120	1000	0.63 ± 0.26	<0.20	1.84 ± 1.01	0.15 ± 0.09
160	360	0.64 ± 0.19	<0.17	0.73 ± 0.61	0.12 ± 0.05
160	400	0.90 ± 0.23	<0.19	0.74 ± 0.60	<0.04
160	440	0.51 ± 0.27	<0.20	1.63 ± 1.94	<0.04
160	480	0.84 ± 0.21	<0.20	0.82 ± 0.69	<0.03
160	520	0.84 ± 0.25	<0.20	1.03 ± 0.74	<0.04
160	560	0.91 ± 0.27	<0.18	0.68 ± 1.97	<0.03
160	600	0.71 ± 0.19	<0.19	1.07 ± 0.76	<0.04
160	640	1.05 ± 0.26	<0.28	1.61 ± 1.88	<0.04
160	680	0.90 ± 0.31	<0.20	<0.93	0.08 ± 0.06
160	720	0.65 ± 0.21	<0.16	0.73 ± 1.42	<0.04

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 40 M AND 20 M GRID INTERVALS

Grid Locations		Radionuclide Concentrations (pCi/g)			
S	E	Ra-226	U-235	U-238	Cs-137
160	760	0.93 ± 0.26	<0.19	0.97 ± 0.65	0.03 ± 0.04
160	800	0.83 ± 0.24	<0.18	<0.84	<0.04
160	840	c	c	c	c
160	880	c	c	c	c
160	920	c	c	c	c
160	960	c	c	c	c
160	1000	0.78 ± 0.19	<0.23	0.90 ± 0.78	0.64 ± 0.14
200	360	0.64 ± 0.27	<0.19	<0.80	0.25 ± 0.11
200	400	0.78 ± 0.24	<0.20	0.96 ± 0.68	<0.03
200	440	1.03 ± 0.27	<0.21	0.84 ± 1.90	<0.03
200	480	0.90 ± 0.24	<0.20	1.37 ± 0.74	<0.03
200	520	1.19 ± 0.43	<0.26	<0.92	<0.04
200	560	1.03 ± 0.30	<0.20	1.92 ± 1.77	<0.03
200	600	0.68 ± 0.24	<0.17	<0.77	<0.03
200	640	0.91 ± 0.29	<0.24	1.09 ± 1.30	<0.04
200	680	1.03 ± 0.24	<0.19	1.28 ± 1.55	<0.04
200	720	0.83 ± 0.25	<0.20	1.39 ± 1.45	<0.03
200	760	1.03 ± 0.23	<0.21	0.48 ± 1.25	<0.04
200	800	0.88 ± 0.26	<0.20	1.47 ± 1.81	<0.04
200	840	c	c	c	c
200	880	c	c	c	c
200	920	c	c	c	c
200	960	c	c	c	c
200	1000	0.91 ± 0.29	<0.24	<1.32	0.70 ± 0.16
240	360	0.90 ± 0.21	<0.20	<0.73	<0.04
240	400	0.99 ± 0.24	<0.20	1.36 ± 1.33	<0.04
240	440	0.83 ± 0.19	<0.20	1.57 ± 1.03	<0.04
240	480	0.81 ± 0.20	<0.20	1.03 ± 0.70	<0.03
240	520	0.78 ± 0.23	<0.22	1.32 ± 1.48	<0.03
240	560	0.91 ± 0.26	<0.20	1.23 ± 2.23	0.05 ± 0.07
240	600	0.91 ± 0.23	<0.19	1.19 ± 0.47	<0.04
240	640	0.66 ± 0.20	<0.20	0.83 ± 0.99	<0.04
240	680	0.84 ± 0.25	<0.19	<0.08	<0.03
240	720	0.81 ± 0.29	<0.20	1.79 ± 1.51	<0.03
240	760	0.88 ± 0.26	<0.22	2.33 ± 1.02	<0.04
240	800	0.93 ± 0.23	<0.15	1.94 ± 1.52	<0.03
240	840	c	c	c	c
240	880	c	c	c	c
240	920	c	c	c	c
240	960	c	c	c	c

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 40 M AND 20 M GRID INTERVALS

Grid Locations S	E	Radionuclide Concentrations (pCi/g) Ra-226	U-235	U-238	Cs-137
330[b]	900	0.88 ± 0.33	<0.27	<0.88	<0.04
330[b]	920	0.93 ± 0.25	<0.20	1.57 ± 1.47	<0.03
330[b]	940	0.91 ± 0.20	<0.20	1.13 ± 1.59	<0.03
330[b]	960	0.78 ± 0.24	<0.21	2.19 ± 1.03	<0.04
320[b]	980	0.96 ± 0.31	<0.19	<0.70	<0.03
320	1000	1.00 ± 0.21	<0.20	1.15 ± 0.46	<0.05
340	680	0.81 ± 0.30	<0.20	1.05 ± 1.85	0.36 ± 0.16
340	700	0.95 ± 0.21	<0.25	1.13 ± 1.02	<0.04
335[b]	720	1.13 ± 0.26	<0.22	1.06 ± 0.93	<0.04
340	740	0.79 ± 0.31	<0.28	1.45 ± 1.74	0.06 ± 0.08
340	760	1.25 ± 0.33	<0.31	<1.05	0.70 ± 0.22
340	780	0.75 ± 0.23	<0.25	2.77 ± 1.53	<0.05
340	800	1.16 ± 0.23	<0.24	0.98 ± 0.83	0.08 ± 0.07
340	820	0.63 ± 0.18	<0.18	0.62 ± 0.69	<0.03
340	840	0.95 ± 0.26	<0.21	<0.84	<0.04
340	860	1.01 ± 0.30	<0.23	<0.87	0.85 ± 0.17
340	880	1.09 ± 0.26	<0.19	1.08 ± 0.69	<0.03
340	900	0.89 ± 0.18	<0.23	0.96 ± 1.61	<0.05
340	920	1.00 ± 0.29	<0.29	2.08 ± 1.71	<0.04
340	940	0.91 ± 0.25	<0.20	0.92 ± 0.86	<0.03
340	960	0.91 ± 0.25	<0.22	0.72 ± 0.69	<0.03
340	980	0.61 ± 0.31	<0.25	<0.87	0.54 ± 0.12
340	1000	0.88 ± 0.18	<0.21	1.07 ± 0.80	<0.04
360	360	[c]	[c]	[c]	[c]
360	400	[c]	[c]	[c]	[c]
360	440	[c]	[c]	[c]	[c]
360	480	[c]	[c]	[c]	[c]
360	520	[c]	[c]	[c]	[c]
360	560	[c]	[c]	[c]	[c]
360	600	0.86 ± 0.20	<0.20	<0.83	0.12 ± 0.12
360	620	0.94 ± 0.29	<0.28	3.37 ± 1.87	<0.04
360	640	1.11 ± 0.31	<0.22	2.11 ± 1.94	0.20 ± 0.11
360	660	0.80 ± 0.20	0.38 ± 0.36	0.84 ± 0.99	0.20 ± 0.09
360	680	0.90 ± 0.23	<0.21	0.94 ± 0.46	0.10 ± 0.05
360	700	1.11 ± 0.31	<0.18	1.93 ± 1.77	0.52 ± 0.13
360	720	1.07 ± 0.30	<0.28	1.27 ± 0.78	0.70 ± 0.18
380	600	0.83 ± 0.26	0.33 ± 0.35	1.27 ± 0.78	<0.04
380	620	1.00 ± 0.33	<0.23	<0.89	0.26 ± 0.12
380	640	0.81 ± 0.38	<0.20	1.36 ± 2.26	0.57 ± 0.13
380	660	1.11 ± 0.30	<0.25	<0.98	0.28 ± 0.10

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES FROM 40 M AND 20 M GRID INTERVALS

Grid Locations		Radionuclide Concentrations (pCi/g)			
S	E	Ra-226	U-235	U-238	Cs-137
240	1000	1.11 ± 0.29	<0.24	0.97 ± 1.30	<0.05
280	360	0.75 ± 0.23	<0.20	<0.79	0.33 ± 0.15
280	400	0.68 ± 0.21	<0.19	1.12 ± 1.46	<0.04
280	440	0.81 ± 0.21	<0.24	1.21 ± 1.69	<0.04
280	480	0.84 ± 0.24	<0.25	<0.85	<0.04
280	520	0.66 ± 0.26	<0.23	1.91 ± 1.62	<0.04
280	560	<0.43	<0.19	0.73 ± 0.36	<0.03
280	600	0.65 ± 0.21	0.37 ± 0.31	0.70 ± 0.62	<0.04
280	640	1.06 ± 0.29	<0.26	1.88 ± 1.55	<0.04
280	680	1.05 ± 0.23	<0.23	0.98 ± 0.48	<0.05
280	720	0.75 ± 0.24	<0.20	1.03 ± 0.68	0.04 ± 0.05
280	760	0.61 ± 0.24	<0.21	0.70 ± 0.92	<0.03
280	800	1.34 ± 0.35	<0.28	1.71 ± 2.25	<0.04
280	815[b]	0.71 ± 0.31	<0.24	2.06 ± 1.49	<0.03
280	840	c	c	c	c
280	880	c	c	c	c
280	920	c	c	c	c
280	960	c	c	c	c
280	1000	1.03 ± 0.24	<0.26	1.34 ± 1.05	<0.05
300	800	0.88 ± 0.29	<0.26	1.53 ± 1.91	<0.04
300	815[b]	0.65 ± 0.23	<0.19	1.16 ± 0.49	<0.03
320	360	c	c	c	c
320	400	c	c	c	c
320	440	c	c	c	c
320	480	c	c	c	c
320	520	c	c	c	c
320	560	0.76 ± 0.24	<0.20	0.97 ± 1.99	0.13 ± 0.07
320	600	0.76 ± 0.29	<0.25	1.37 ± 1.46	0.14 ± 0.12
320	640	0.81 ± 0.23	<0.20	1.30 ± 0.90	0.06 ± 0.04
320	680	0.63 ± 0.29	<0.19	<0.43	0.11 ± 0.07
320	700	0.89 ± 0.20	<0.18	1.73 ± 1.80	0.29 ± 0.13
320	720	0.91 ± 0.20	<0.22	1.52 ± 1.39	0.22 ± 0.11
320	740	0.69 ± 0.24	<0.18	<0.74	0.12 ± 0.09
320	760	0.68 ± 0.39	<0.23	1.00 ± 0.75	0.23 ± 0.07
320	780	0.76 ± 0.21	<0.17	1.68 ± 0.88	0.07 ± 0.05
320	800	0.75 ± 0.24	<0.16	<0.73	0.40 ± 0.13
320	820	0.88 ± 0.25	<0.20	0.93 ± 0.87	<0.03
330[b]	840	0.80 ± 0.29	<0.24	1.55 ± 1.46	<0.04
330[b]	860	0.88 ± 0.24	<0.18	0.99 ± 0.59	<0.03
330[b]	880	0.75 ± 0.23	<0.27	1.65 ± 1.00	<0.03

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 40 M AND 20 M GRID INTERVALS

Grid Locations		Radionuclide Concentrations (pCi/g)			
S	E	Ra-226	U-235	U-238	Cs-137
380	680	0.85 ± 0.24	<0.18	1.55 ± 1.54	<0.04
380	700	0.64 ± 0.20	<0.17	1.74 ± 1.09	0.22 ± 0.08
380	720	1.34 ± 0.29	<0.23	<1.00	1.24 ± 0.23
400	360	0.99 ± 0.26	<0.18	<0.75	0.18 ± 0.09
400	400	0.86 ± 0.27	<0.27	1.55 ± 1.83	0.20 ± 0.11
400	440	0.63 ± 0.31	<0.24	0.96 ± 1.04	0.12 ± 0.12
400	480	0.75 ± 0.27	<0.18	<0.86	0.19 ± 0.08
400	520	0.86 ± 0.31	<0.28	<1.01	0.19 ± 0.09
400	560	0.99 ± 0.34	<0.27	1.27 ± 1.69	<0.05
400	600	0.79 ± 0.19	<0.25	<0.92	0.29 ± 0.10
400	620	1.16 ± 0.33	<0.22	1.40 ± 0.91	0.09 ± 0.09
400	640	0.99 ± 0.33	<0.26	<0.96	<0.05
400	660	0.63 ± 0.16	<0.17	1.25 ± 0.61	0.49 ± 0.11
400	680	1.34 ± 0.39	<0.35	2.02 ± 2.80	0.97 ± 0.20
400	700	0.83 ± 0.31	<0.28	1.12 ± 2.21	0.93 ± 0.14
400	720	0.66 ± 0.25	<0.25	0.39 ± 0.99	1.04 ± 0.15

a Errors are 2σ based on counting statistics.
b Nearest accessible location to systematic grid point was sampled.
c Area covered by water or active waste operations; sample not available.

TABLE 5

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
FROM LOCATIONS IDENTIFIED BY THE WALKOVER SCAN

Sample No.	Grid Location	Radionuclide Concentrations (pCi/g)[a]			
		Ra-226	U-235	U-238	Cs-137
B1	34S,360E	7.20 ± 0.61[b]	<0.53	12.6 ± 2.3	<0.07
B2	130S,720E	c	c	c	c
B3	10S,677E	5.31 ± 0.45	<0.44	2.70 ± 2.82	<0.05
B4-A soil	11S,510E	22.4 ± 1.0	<0.61	<1.71	0.26 ± 0.11
B4-B chip	11S,510E	d	d	d	d
B5	108S,358E	21.4 ± 0.9	1.11 ± 0.97	10.7 ± 1.8	<0.18
B6[e]	140S,483E	1.41 ± 0.55	<0.20	2.11 ± 1.63	<0.14
B7[f]	128S,523E	1.43 ± 0.64	<1.13	4.28 ± 4.44	<0.83

a Direct Radiation levels are presented in Table 3.
b Errors are 2σ based on counting statistics.
c Activity level was too high for routine gamma spectrometry; analysis indicates total Ra-226 activity of 20 μCi in small chip of lead cake.
d Activity level was too high for routine gamma spectrometry; analysis indicates total Ra-226 activity of 2.8 μCi in small chip of lead cake.
e Also contained 10.9 ± 0.5 pCi/g of Ag-110m and 0.36 ± 0.26 pCi/g of Co-60.
f Also contained 27.7 ± 0.8 pCi/g of Ag-110m and 0.98 ± 0.42 pCi/g of Co-60.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No.[a]	Grid Location	Depth (m)	Radionuclide Concentrations (pCi/g) Ra-226	U-235	U-238	Cs-137
H1	106S,357E	Surface	0.78 ± 0.36[b]	<0.19	<0.72	<0.03
		0.5	0.84 ± 0.30	<0.19	<0.82	<0.03
		1.0	0.86 ± 0.29	<0.32	<0.97	<0.04
		2.0	0.90 ± 0.24	<0.17	<0.74	<0.03
H2	291S,349E	Surface	0.63 ± 0.24	<0.17	0.38 ± 0.30	<0.04
		0.5	0.80 ± 0.23	<0.27	2.93 ± 1.04	<0.04
		1.0	0.66 ± 0.16	<0.17	0.50 ± 0.64	<0.03
		2.0	0.74 ± 0.24	<0.20	1.26 ± 0.51	0.02 ± 0.06
H3	12S,500E	Surface	0.79 ± 0.25	<0.19	0.99 ± 1.32	0.07 ± 0.04
		0.5	1.00 ± 0.20	<0.22	1.31 ± 0.52	<0.03
		1.0	0.28 ± 0.26	<0.18	1.70 ± 0.99	<0.03
		2.0	0.78 ± 0.28	<0.23	1.83 ± 1.75	<0.03
H4	14S,792E	Surface	0.78 ± 0.20	<0.20	0.97 ± 0.62	0.06 ± 0.05
		0.5	0.56 ± 0.24	<0.22	0.88 ± 0.81	<0.03
		1.0	0.71 ± 0.23	<0.27	<0.76	<0.04
H5	10S,990E	Surface	1.09 ± 0.24	<0.28	3.43 ± 1.96	0.30 ± 0.10
		0.5	0.83 ± 0.23	<0.21	1.08 ± 0.76	<0.05
		1.0	0.83 ± 0.24	<0.20	0.88 ± 1.52	<0.04
H6	189S,1000E	Surface	1.04 ± 0.21	<0.23	0.63 ± 0.71	0.40 ± 0.10
		0.5	0.78 ± 0.21	<0.26	2.47 ± 1.44	<0.03
		1.0	0.81 ± 0.23	<0.19	<0.72	<0.03
		2.0	1.03 ± 0.24	<0.20	<0.82	<0.03
H7	304S,1008E	Surface	1.00 ± 0.20	<0.18	1.28 ± 1.90	<0.03
		0.5	1.49 ± 0.28	<0.20	<0.87	<0.04

a Refer to Figure 4.
b Errors are 2σ based on counting statistics.

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE WATER SAMPLES

Sample ID	Sample Type	Grid Location	Radionuclide Concentration (pCi/l)			
			Gross Alpha[a]	Gross Beta	Ra-226	Sr-90
W1	Subsurface (borehole H1)[b]	108S, 357E	<8.60	102 ± 25[a]	1.47 ± 0.17	<0.27
W2	" (" H2)[b]	291S, 349E	<2.65	4.32 ± 6.10	---	---
W3	" (" H3)[b]	12S, 500E	16.6 ± 3.3	19.1 ± 4.4	0.33 ± 0.15	---
W4	" (" H4)[b]	14S, 792E	<1.45	18.6 ± 3.7	---	---
W5	" (" H5)[b]	10S, 990E	9.96 ± 5.46	6.25 ± 6.94	0.09 ± 0.07	---
W6	" (" H6)[b]	189S,1000E	21.5 ± 8.6	22.5 ± 12.5	0.19 ± 0.16	---
W7	" (" H7)[b]	304S,1008E	2.57 ± 4.71	2.80 ± 6.85	<0.05	---

[a] Large amounts of dissolved solids resulted in relatively poor detection sensitivities and high errors for gross alpha analysis.
[b] Refer to Figure 4.
[c] Errors are 2σ based on counting statistics.
[d] Dash indicates analysis not performed.

REFERENCES

1. E.A. Vierzba and A. Wallo, Background Report and Resurvey Recommendations for the Atomic Energy Commission Portion of the Lake Ontario Ordnance Works, Aerospace Corp., November 1982.

2. Oak Ridge Operations, U.S. Atomic Energy Commission, Radiation Survey and Decontamination Report of the Lake Ontario Ordnance Works Site, Oak Ridge, TN, January 1973.

3. T.E. Myrick, et al., Preliminary Results of the Ground-Level Gamma-Ray Scanning Survey of the Former Lake Ontario Ordnance Works Site -- Draft Report, ORNL, Oak Ridge, TN, 1981.

APPENDIX A

INSTRUMENTATION AND ANALYTICAL PROCEDURES

APPENDIX A

Instrumentation and Analytical Procedures

Gamma Scintillation Measurements

Walkover surface scans and measurements of gamma exposure rates were performed using Eberline Model PRM-6 portable ratemeters with Victoreen Model 489-55 gamma scintillation probes containing 3.2 cm x 3.8 cm NaI(Tl) crystals. Count rates were converted to exposure levels (μR/h) using factors determined by comparing the response of the scintillation detector with that of a Reuter Stokes model RSS-111 pressurized ionization chamber at several locations on the Niagara Falls Storage Site and off-site properties.

Beta-Gamma Dose Rate Measurements

Measurements were performed using Eberline "Rascal," Model PRS-1, portable ratemeters with Model HP-260 thin-window, pancake G-M, beta probes. Dose rates (μrad/h) were determined by comparison of the response of a Victoreen Model 440 ionization chamber survey meter to that of the G-M probes.

Borehole Logging

Borehole gamma radiation measurements were performed using a Victoreen Model 489-55 gamma scintillation probe, connected to a Ludlum Model 2200 portable scaler. The scintillation probe was shielded by a 1.25 cm thick lead shield with four 2.5 cm x 7 mm holes evenly spaced around the region of the scintillation crystal. The probe was lowered into each hole using a tripod holder with a small winch. Measurements were performed at 15-30 cm intervals in all holes. The logging data was used to identify regions of possible residues and guide the selection of subsurface soil sampling locations. Due to the varying ratios of Ra-226, U-235, U-238, and Cs-137, which occur on the NFSS off-site properties, there was no attempt to estimate soil radionuclide concentrations directly from the logging results.

Soil Sample Analysis

Gamma Spectrometry

Soil samples were dried, mixed, and a portion placed in a 0.5 liter Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and typically ranged from 600 to 800 g of soil. Net soil weights were determined and the samples counted using solid state intrinsic germanium and Ge(Li) detectors coupled to a Nuclear Data model ND-680 pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

Ra-226 - 0.609 MeV from Bi-214 (corrected for equilibrium conditions)
U-235 - 0.143 MeV
U-238 - 0.093 MeV from Th-234 (secular equilibrium assumed)
Cs-137 - 0.662 MeV
Co-60 - 1.332 MeV
Ag-110m - 0.447 MeV

Water Sample Analysis

Water samples were rough-filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by subsequent filtration through 0.45 µm membrane filters. The filtrate was acidified by addition of 10 ml of concentrated nitric acid. Ten to fifty milliliters (depending on dissolved solid content) of each sample was evaporated to dryness and counted for gross alpha and gross beta using a Tennelec Model LB 5100 low-background proportional counter.

Analysis for Ra-226 was performed using the standard technique EPA 600/4-75-008 (revised). Analysis for Sr-90 was performed according to methods described in "Radiochemical Analytical Procedures for Analysis of Environmental Samples," EMSL-LV-0539-17, March 1979.

Calibration and Quality Assurance

With the exception of determining the site specific exposure and dose rate conversion factors for portable survey gamma and beta-gamma meters, all survey and laboratory instruments were calibrated with NBS-traceable standards.

Quality control procedures on all instruments included daily background and check-source measurements to confirm lack of malfunctions and nonstatistical deviations in equipment. The ORAU laboratory participates in the EPA Quality Assurance Program.

APPENDIX B

SUMMARY OF RADIATION GUIDELINES APPLICABLE TO OFF-SITE PROPERTIES AT THE NIAGARA FALLS STORAGE SITE

U. S. DEPARTMENT OF ENERGY

RESIDUAL CONTAMINATION AND WASTE CONTROL CRITERIA FOR FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM (FUSRAP) AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM (SFMP) SITES

Presented here are the residual contamination cleanup and waste control criteria of general applicability to the FUSRAP project and remote SFMP sites[1/].

With the exception of limits for radium-226, the soil residual contamination criteria were developed on the basis of limiting maximum individual radiation exposure to DOE limits specified in DOE Order 5480.1A exclusive of exposure from natural background radiation or medical procedures. The aggregate of the contribution from all major pathways, based on scenarios for permanent intrusion, e.g., establishing residences on the site, has been assumed. In most circumstances, the probability is low that such an intrusion will occur. Also, conservative assumptions were used in deriving these criteria to ensure that a particular dose limit would not be exceeded. Use of these criteria is additionally conservative because the pathways considered in the derivation of the criteria assume all water intake and most food intake is from the site. Also, the sites often have limited agricultural capability and the contamination is generally not homogeneous. The combined effect of these factors is such that the probable radiation exposure to the average population on, or in the vicinity of, FUSRAP sites decontaminated to these criteria limits will not be appreciably different from that normally received from natural background radiation.

The residual contamination criteria for surface contamination of structures were developed from a proposed ANSI standard[2/] modified as appropriate to be consistent with DOE Order 5480.1A and the specific needs of FUSRAP for cost-effective, workable guidelines which provide an adequate safety margin. The waste control criteria are consistent with applicable DOE Orders and EPA's regulations for inactive uranium milling sites, 40 CFR 192.

[1/] A remote SFMP site is one that is excess to DOE programmatic needs and is located outside a major operating DOE R&D or production area. Remote sites are more likely to be released to the public or excessed to other government agencies after decontamination than are sites located with major R&D or production areas.

[2/] ANSI N13.12 (proposed) -- an adaptation to be applied, as appropriate.

A. RESIDUAL CONTAMINATION CRITERIA FOR FORMERLY UTILIZED SITES AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES

The following criteria represent the maximum residual contamination limits for unrestricted use of land and structures contaminated with radionuclides related to the nuclear fuel cycle at FUSRAP and remote SFMP sites. It is the policy of DOE to decontaminate sites to contamination levels at or below the limits and in a manner consistent with DOE's as-low-as-is-reasonably-achievable (ALARA) policy. Residual contamination limits for other nuclides will be developed when required using the same methodology[1/] as was used for those represented here.

1. Soil (Land) Criteria (Maximum Limits for Unrestricted Use)

Radionuclide	Soil Criteria[2/,3/,4/] (pCi/g above background)
U-Natural[5/]	75
U-238[6/]	150
U-234[6/]	150
Th-230[7/]	15
Ra-226	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over 15 cm thick soil layers more than 15 cm below the surface and less than 1.5m below the surface.
U-235[6/]	140
Pa-231	40
Ac-227	190
Th-232	15
Am-241	20
Pu-241[8/]	800
Pu-238, 239, 240	100
Cs-137	80
Sr-90	100
H-3 (pCi/ml soil moisture)	5,200

1/ Described in ORO-831 and ORO-832.

2/ In the event of occurrence of mixtures of radionuclides, the fraction contributed by each radionuclide to its limit shall be determined, and the sum of these fractions shall not exceed 1. There are two special cases for which this rule must be modified:

(a) If Ra-226 is present, then the fraction for Ra-226 should not be included in the sum if the Ra-226 concentration is less than or equal to the Th-230 concentration. If the Ra-226 concentration exceeds the Th-230 concentration, then the sum shall be evaluated by replacing the Ra-226 concentration by the difference between the Ra-226 and Th-230 concentrations.

(b) If Ac-227 is present, then the same rule given in (a) for Ra-226 relative to Th-230 applies for Ac-227 relative to Pa-231.

3/ Except for Ra-226, these criteria represent unrestricted-use residual concentrations above background averaged across any 15 cm thick layer to any depth and over any contiguous 100 m^2 surface area. The same conditions prevail for Ra-226 except for soil layers beneath 1.5 m; beneath 1.5 m, the allowable Ra-226 concentration may be affected by site-specific conditions and must be evaluated accordingly.

4/ Localized concentrations in excess of these limits are allowable provided that the average over 100 m^2 is not exceeded.

5/ A curie of natural uranium means the sum of 3.7×10^{10} disintegrations per second (dis/s) from U-238 plus 3.7×10^{10} dis/s from U-234 plus 1.7×10^{9} dis/s from U-235. One curie of natural uranium is equivalent to 3,000 kilograms or 6,600 pounds of natural uranium.

6/ Assumes no other uranium isotopes are present.

7/ The Th-230 guideline is 15 pCi/g to account for ingrowth of Ra-226 as Th-230 decays. Ra-226 is a limiting radionuclide because its decay product is Rn-222 gas.

8/ The Pu-241 criterion was derived from the Am-241 concentration.

2. Structure Criteria (Maximum Limits for Unrestricted Use)

a. Indoor Radon Decay Products

A structure located on private property and intended for unrestricted use shall be subject to remedial action as necessary to ensure the annual average concentration of radon decay products is less than 0.03 WL within the structure.

b. Indoor Gamma Radiation

The indoor gamma radiation after decontamination shall not exceed 20 microroentgen per hour (20 μR/h) above background.

c. Indoor/Outdoor Structure Surface Contamination

Radionuclides	Allowable Surface Residual Contamination[1] ($dpm/100\ cm^2$) Total	Removable
Group 1:	100	20
Radionuclides for which the uncontrolled area concentration guide in air above background[2] is 2×10^{-13} Ci/m^3 or less or for which the uncontrolled area concentration guide in water above background[2] is 2×10^{-7} Ci/m^3 or less; includes Pa-231, Th-228, Th-230, Ac-227, Ra-226, Ra-228, and Pb-210.		
Group 2:	1,000	200
Radionuclides not in Group 1 for which the uncontrolled area concentration guide in air above background[2] is 1×10^{-12} Ci/m^3 or less or for which the uncontrolled area concentration guide in water above background[2] is 1×10^{-6} Ci/m^3 or less; includes U-232, U-238, Th-232, Ra-223, and Po-210.		
Group 3:	5,000	1,000
Those radionuclides not in Group 1 or Group 2; includes U-234, U-235, and Ra-224 and all other beta-gamma emitters.		

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[1] The levels may be averaged over 1 m^2 provided the maximum activity in any area of 100 cm^2 is less than 3 times the limit value; dpm = disintegrations per minute. In the event of occurrence of mixtures of radionuclides, the fraction contributed by each radionuclide to its limit shall be determined, and the sum of these fractions shall not exceed 1.

[2] Given in Attachment 1 to Chapter XI, Table II, DOE Order 5480.1A.

B. CONTROL OF RADIOACTIVE WASTES AND RESIDUES FROM FUSRAP AND REMOTE SFMP SITES

Specified here are the control requirements (criteria) for radioactive wastes and residues related to the nuclear fuel cycle at FUSRAP and remote SFMP sites.

1. Interim Storage

All operational and control requirements specified in the following DOE Orders shall apply:

a. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations.

b. 5480.2, Hazardous and Radioactive Mixed Waste Management.

c. 5483.1, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities.

d. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements.

e. 5484.2, Unusual Occurrence Reporting System.

f. Control and stabilization features will be designed to ensure, to the extent reasonably achievable, an effective life of 50 years, and in any case, at least 25 years.

g. Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not (1) exceed 100 pCi/l at any given point, or an average concentration of 30 pCi/l for the facility site, or (2) exceed an average Rn-222 concentration at or above any location outside the facility site of 3.0 pCi/l (above background).

h. For water protection, use existing state and federal standards; apply site-specific measures where needed.

2. Long-Term Management

a. All operational requirements specified for Interim Storage Facilities (B.1) will apply.

b. Control and stabilization features will be designed to ensure to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years. Other disposal site design features shall conform with 40 CFR Part 192 performance guidelines/requirements.

c. Rn-222 emanation to the atmosphere from facility surfaces or opening shall not (1) exceed an average release rate of 20 pCi/m^2/s, or (2) increase the annual average Rn-222 concentration at or above any location outside the facility site by more than 0.5 pCi/l.

d. For water protection, use existing state and federal standards; apply site-specific measures where needed.

e. Prior to placement of any potentially biodegradable contaminated wastes in a Long-Term Management Facility, such wastes will be properly conditioned to (1) ensure that the generation and escape of biogenic gases will not cause the criteria in paragraph 2.c. to be exceeded, and (2) ensure that biodegradation within the facility will not result in premature structural failure not in accordance with the criteria in paragraph 2.b.. If biodegradable wastes are conditioned by incineration, incineration operations will be carried out in compliance with all applicable federal, state, and local air emission standards and requirements, including any standards for radionuclides established pursuant to 40 CFR Part 61, National Emission Standards for Hazardous Air Pollutants (NESHAPS).

C. EXCEPTIONS

1. Procedure -- Analysis of site-specific conditions.

2. Applicability -- Where health and safety would be endangered, or where cost clearly outweighs benefits.

D. CRITERIA SOURCE

Criteria	Source
Residual Contamination Criteria[1/]	
Soil Criteria	DOE Order 5480.1A, 40 CFR Part 192[2/]
Structure Criteria	40 CFR Part 192, proposed ANSI N13.12.
Control of Radioactive Wastes and Residues	
Interim Storage	DOE Order 5480.1A
Long-Term Management	40 CFR Part 192

Exceptions

Procedure	40 CFR Part 192
Applicability	40 CFR Part 192

1/ The bases of the residual contamination criteria are developed in ORO-831 as supplemented and ORO-832.

2/ Based on limiting the concentration of radon-222 decay products to 0.03 WL within structures.